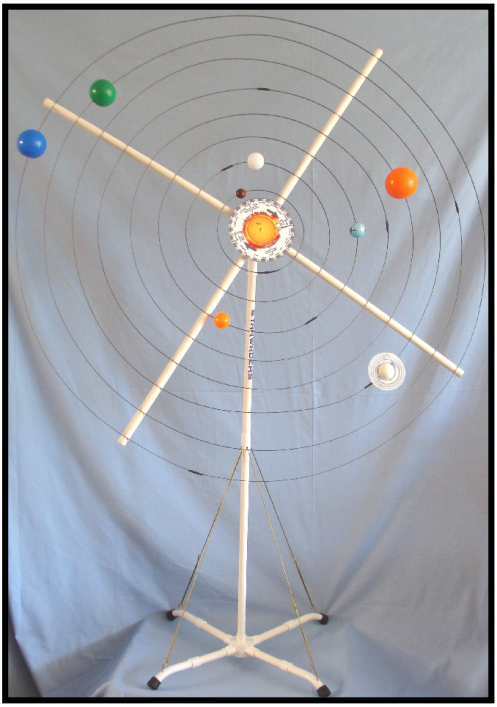
STARWADERS

Portable Solar System Model



Instruction Manual

v1-40912

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Version History:

V1-20714 – Introduction of PVC model
V1-20714 – Added stabilizer cord
V1-40610 – Added base modifications, stays and new rotation ring
V1-40912 – Added Sun disk explanation and instructions

1 PREFACE

This user manual shows how to build the model and how to use it to explain why we see the planets where they appear in the sky.

1.1 The Structure of this Booklet?

- Following this introductory preface is a general description of the model.
- Thereafter follow instructions on how to use the model.

1.2 Improvements

The PSSM continues to be upgraded, making assembly more reliable, speedier and easier. This latest manual includes the design improvements in the model until September 2014.

1.3 Contact Starwaders

- jen@starwaders.com
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2 The Design

- The planet orbits are made of concentric hoops, which fit onto a frame comprising four arms.
- The planets are made of hollow plastic balls with a slot halfway through them, so that they can easily slide onto the concentric hoops.
- There is no attempt to scale the orbits and planets proportionally. When thought about carefully, this would require a model as large as a football stadium and the smaller planets would be no larger than the period at the end of this sentence. There is a LOT of Space out there!

A revealing analogy to show how much space there really is, is to hold your hands outstretched to your sides with palms up. If the Sun and the Earth were placed on opposite palms, what size should they be in proportion to the distance between them?

The Sun would be the size of a pea and the Earth would fit inside the thickness of a standard sheet of 80gram printing paper!

Venus would be about the same size and would be placed on the shoulder closest to the Earth.

2.1 The Planets

The objects representing the planets are balls of different sizes in appropriate colours which allows a school child with a little knowledge to identify them easily.

The planets each have a slot cut in one half of the sphere allowing them to be mounted onto the hoop.

Planet	Colour
Mercury	Purple
Venus	White
Earth	Earth Map
Mars	Red
Jupiter	Orange
Saturn	Apricot
Uranus	Green
Neptune	Blue

NOTE: The stated colours are not always available and so planet balls are marked with the letter of the planet to avoid confusion.

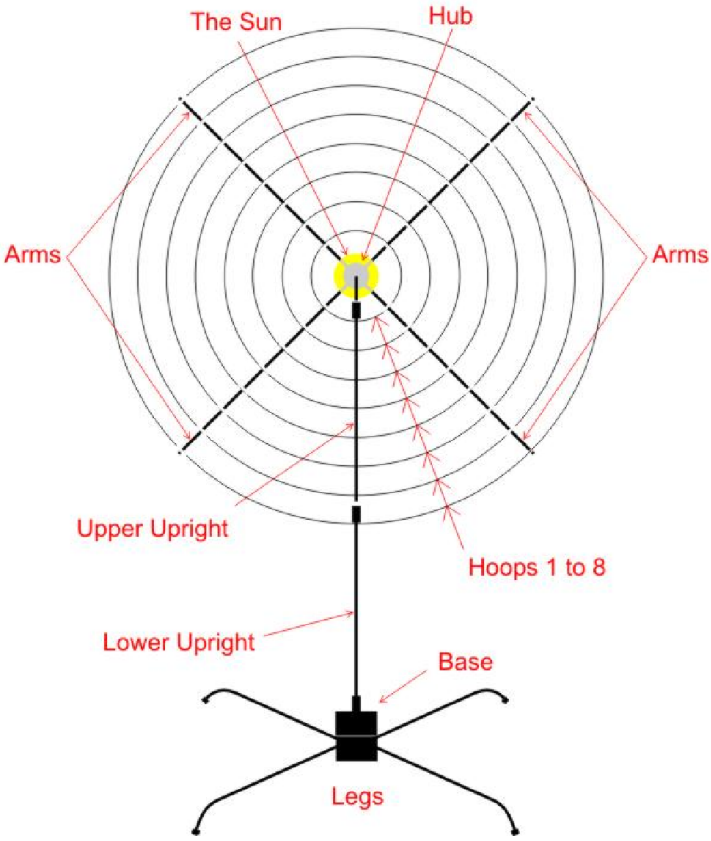
2.2 The Sun

The Sun is represented on a disk which shows the rotation direction of the planets. See instructions on how to use the Sun disk on page15.

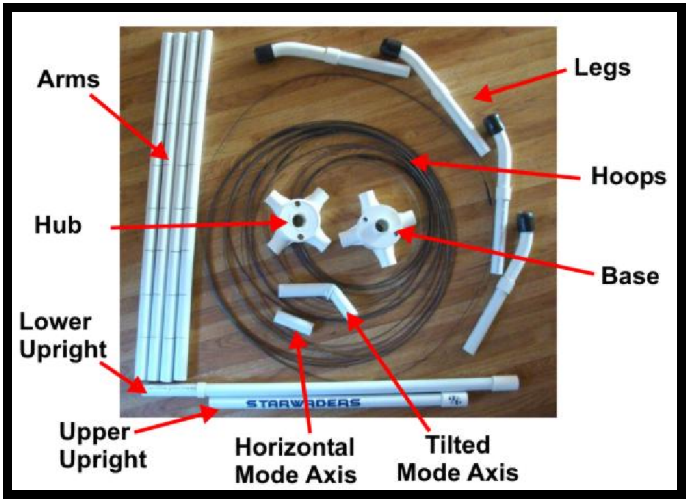
3 Assembling the Model

When children are part of the audience, this is time for fun. They can build the tripod, frame and attach the orbit hoops. Show them the planets and tell them to get on with building the Solar System. This activity provokes lively argument amongst the children as they put the hoops into the correct slots and decide which planet goes where.

The structure is made from PVC pipe held in place by various PVC joining pieces.



The Parts of the PSSM



Follow these instructions to assemble the model:

- Build the stand by inserting the legs into the base.
- Hook the stays into the holes in the legs and adjust stays so that the upright stands straight up and is stable.
- Fit the upper upright into the top of the lower upright.
- Fit the bent axis into the top of the upper upright.

  NOTE: Normally use the bent Tilted Mode axis. For use where the frame is horizontal, use the Horizontal Mode axis.

- Insert the arms into the sleeves around the hub. Ensure that the slits in the arms are facing towards the front and that the long gap between the end and the slit inserts into the sleeves.
- Fit the neck of the hub onto the axis with the side where the screws are facing forwards.

Note that the height of the frame can be made lower for young children by only using one of the uprights.

The Hoops

- The folded hoops are springy and the tightly folded Mars hoop can spring open. When loosening the strap that holds the hoops together, take care that the Mars hoop does not spring open. For this reason, mount the Mars hoop onto the arms first.
- Mount the hoops by centering them over the frame and press the hoop into the corresponding slots on each arm. This can be made slightly easier by gently but imperceptibly bending the arm backwards at the slot. This opens the slot enough to allow the hoop to pop into the slot.
- Do the same with the other 7 orbit hoops.
- Fit the 'Direction of Rotation' sign over the hub and then mount the Sun into the neck on the front of the hub.
- Mount the planets anywhere on the correct hoop. Fit the set of rings onto Saturn.

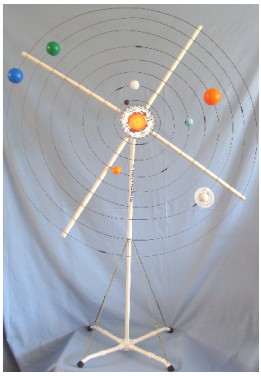
An artificial horizon is included in the kit. It can also be used as a pointer. Join the two halves using the pointer joining block. (Insert the end of the rods with a slit into the joining piece.)

NOTE: In cases where a breeze perhaps sways the frame to and fro, connect the supplied stabiliser cord from the small hole in foot to the small hole in the axis.

4 Using the Model

4.1 Setting Up

Children have a lot of fun fitting the hoops onto the frame, determining which ball represents which planet and then placing the planets on the hoops. They have to know the order of the planets and must be careful not to skip a hoop or to put two planets on one hoop. They find it amusing when it is pointed out to them that two planets in the same orbit will crash into each other.



4.2 The View from the Top – or the Bottom?

We are in the Southern Hemisphere. The classical view of the Solar System is looking down from above the North Pole, in which case the planet's orbits are anti-clockwise. Viewers looking towards the ecliptic (the path along which the planets move) in the northern hemisphere will stand with their backs facing the North Pole and be able to imagine the planets moving against the background stars along their orbits from west to east or right to left.

However, looking down on the Solar System from above the South Pole, the planets orbit in a clockwise fashion. Thus, in the southern hemisphere with our backs to the South Pole when viewing the ecliptic, the planets will still move from west to east but now from left to right.

This instruction manual is applicable to a viewer in the southern hemisphere.

Beware of confusing the movement across the night sky from dusk till dawn with the motion of the planets along their orbits. The former daily movement is due to the rotation of the Earth on its own axis. The latter orbital movement is due to the movement of the planets in their orbits around the Sun.

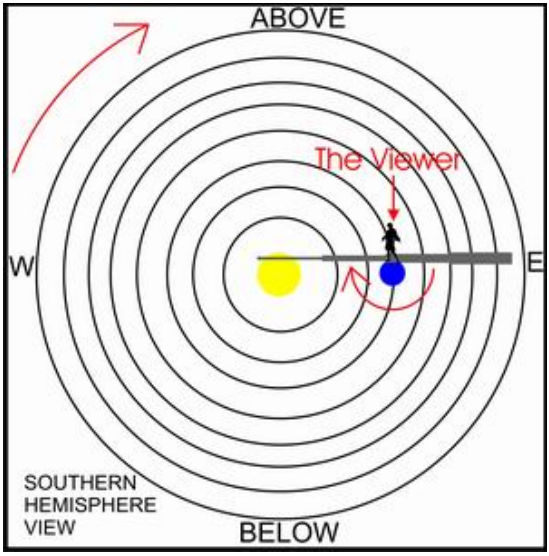
4.3 Orientation

The whole idea behind this Solar System model is to help viewers to relate their horizontal feet-on-the-ground position on Earth to the orbits of the planets 'out in space'.

The frame is tilted so that its plane aligns roughly with the plane of the real solar system. Consider the following situations. At the equator, the plane of the model orbits would then stand vertically like a wall. Viewing from the poles (not likely!) the plane of the model orbits would be positioned horizontally like a tabletop. The tilt for you varies according to your latitude between those two extremes. The tilt of the model is designed for approximately 30º. In the southern hemisphere, when facing the model with your back to the south, the left hand side of the model will be to your west and the right hand side of the model will be to your east.

4.4 Mimicking Sunset

In the evening as the sun sets in the west, place Earth on a level with the Sun on the eastern side of the model. This means that little humans living on the surface of the model Earth will see their plastic Sun in the west. The relative orientations of the real Earth and Sun are now the same as the relative orientations of the model Earth and Sun.



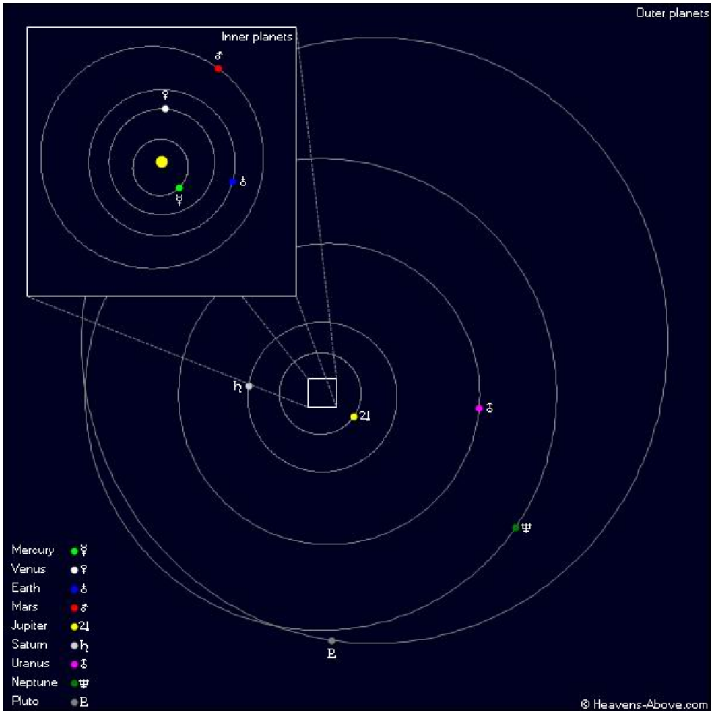
The little humans on their plastic world stand more-or-less ‘upright’, orientated similarly to the real world viewer. This overcomes the difficulty of having to imagine the disorientating situation where a person is ‘standing’ horizontally or ‘upside down’.

With the model in this orientation, and the horizon pointer placed from Earth to the Sun, allow the viewer to look from east along the model 'horizon'. They can easily see that the real Sun and the model 'Sun' are disappearing below the horizon. Put some action into the observation and keeping the 'horizon' at a tangent to the "Earth', rotate the 'horizon' clockwise from a little below the 'Sun' until the 'Sun' disappears below the 'horizon'. This observation mimics a sunset.

This picture and some others show the original prototype model

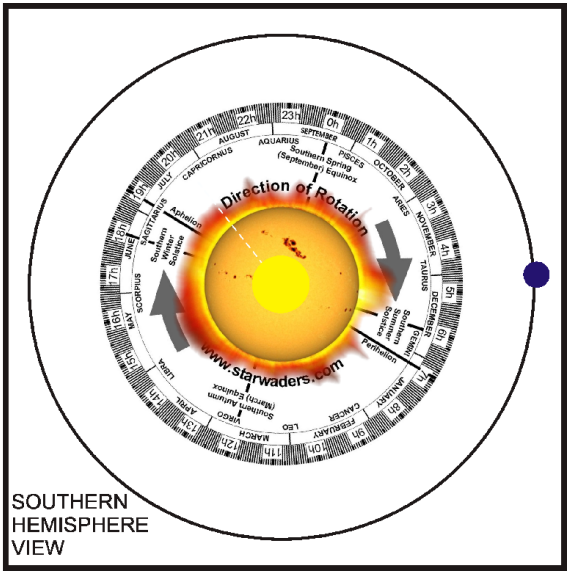
4.5 Planet Positions

We now place the planets in the positions on the hoops corresponding to their actual positions. To do this (unless you know them well enough to keep their movements in your head) you will need a Solar System chart for that evening. You are more than likely to have your own preferred astronomy program to do this for you, but in case not, go to www.heavens-above.com and scroll down to the Solar System Chart link to see the positions as shown in this picture.



Bear in mind that the heavens-above diagram shows the orbits from the North and that movement of the planets is in a clockwise direction of the orbits. Simply make a mirror image in your mind and swop each planet left to right and visa versa. Your own astronomy program will probably be able to show you the orbits viewed from the south.

4.6 Using the Sun Disk



The Sun disk is usually used simply to represent the Sun. However, the disk includes indications of the positions of the zodiacal constellations, the months of the year and the angular position around Earth in which planets are. In order to use these indicators, place the Earth on the hoop in the direction of the current month on the disk, or – of course - simply rotate the disk so that the current month points in the direction of where the Earth has been placed on the model.

Constellations of the Zodiac

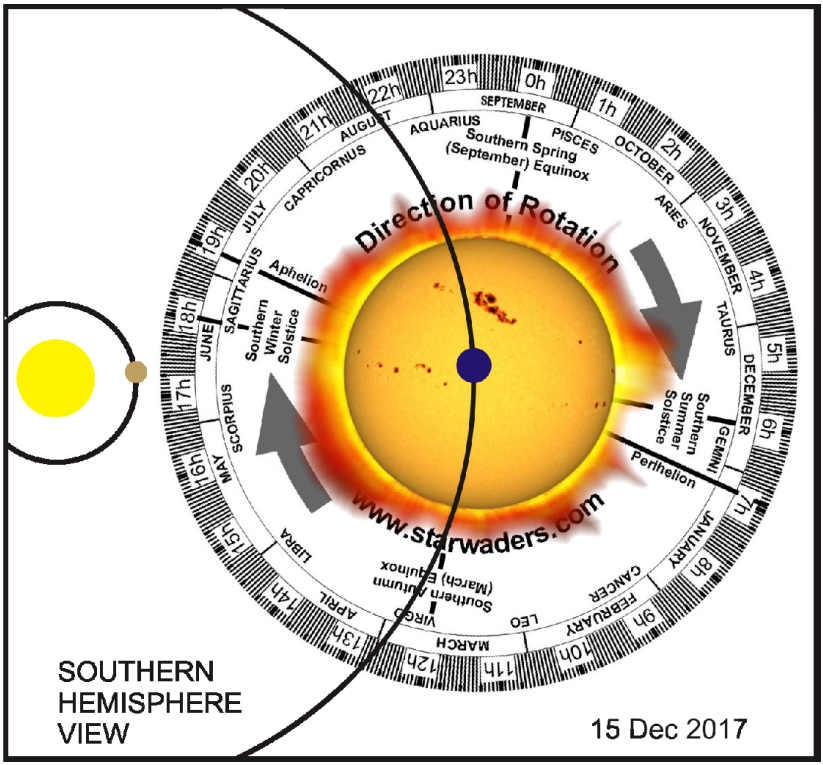
Relative to the Sun, and equally relative to the Earth are the directions of the constellations. For instance, if the Sun is in Scorpius as shown in the diagram, rotate the disk so that Scorpius is on the opposite side of the Sun from where the Earth is on its hoop. The other constellations will now be in their correct positions, such as Taurus which will then be on the midnight side of Earth, therefore overhead at midnight.

Months of the Year

Once the disk has been rotated as in the example above, it can be seen at which month of the year each constellation is overhead at midnight Example: When Taurus is overhead at midnight, it is approximately November/December.

Planet Positions

The indicator scale on the outside of the disk is Right Ascension (RA) in hours, (the celestial equivalent of the lines of longitude on the surface of Earth). Note carefully that this indicator must be seen relative to Earth, that is, as if it were centred on the Earth. This is because positions in RA at any time are given relative to Earth. These RA positions can readily be found at www.heavens-above.com.



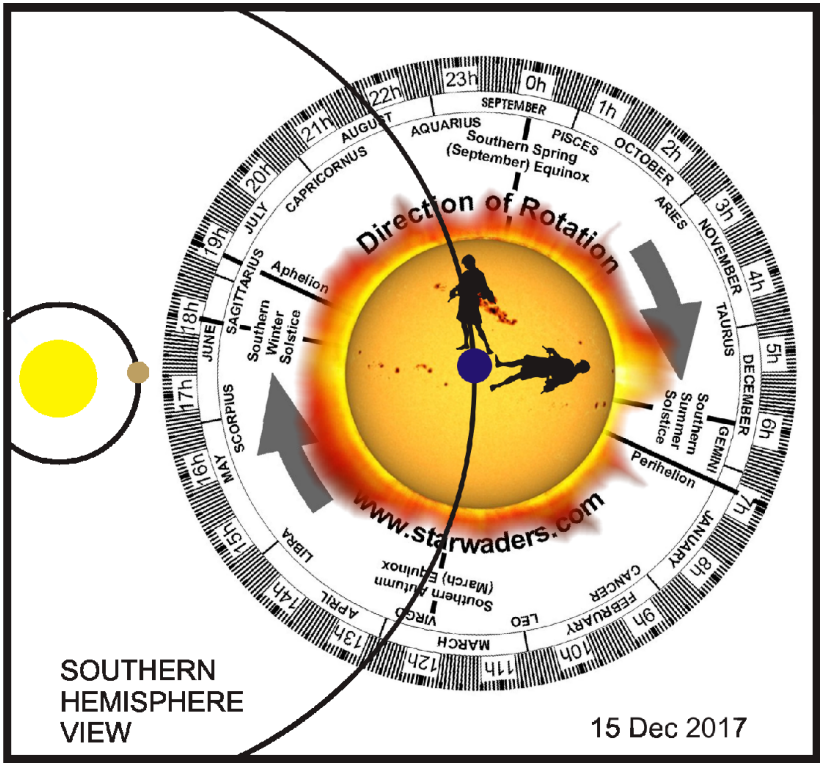
Example:, If it is December, AND let us suppose that Mercury happens to be between the Sun and the Earth (as it will next be in December 2017 for example), the RA for Mercury as read from the heavens-above.com website will then be 17h15 as can be seen in the diagram. Note that Mercury's RA would read incorrectly off the Sun disk if the disk were Sun centred. Note again, that the Sun disk

is not physically placed over the Earth – it is only imagined to be there for the purpose of reading RA which is Earth- centred.

Sidereal Time

This is the time relative to the stars. Our time is usually given with reference to the Sun, with midnight anywhere being 0h00 all year around. If we instead took time relative to the stars, where the stars at the Aquarius/Pisces border represent 0h00, sidereal time anywhere on Earth would then be the RA of the meridian, that is, the line directly overhead form pole to pole.

The RA indicator on the Sun disk shows the sidereal time In the diagram below at sunset (upright figure), the sidereal time is about 23h30. At midnight (horizontal figure) the sidereal time is about 5h30.

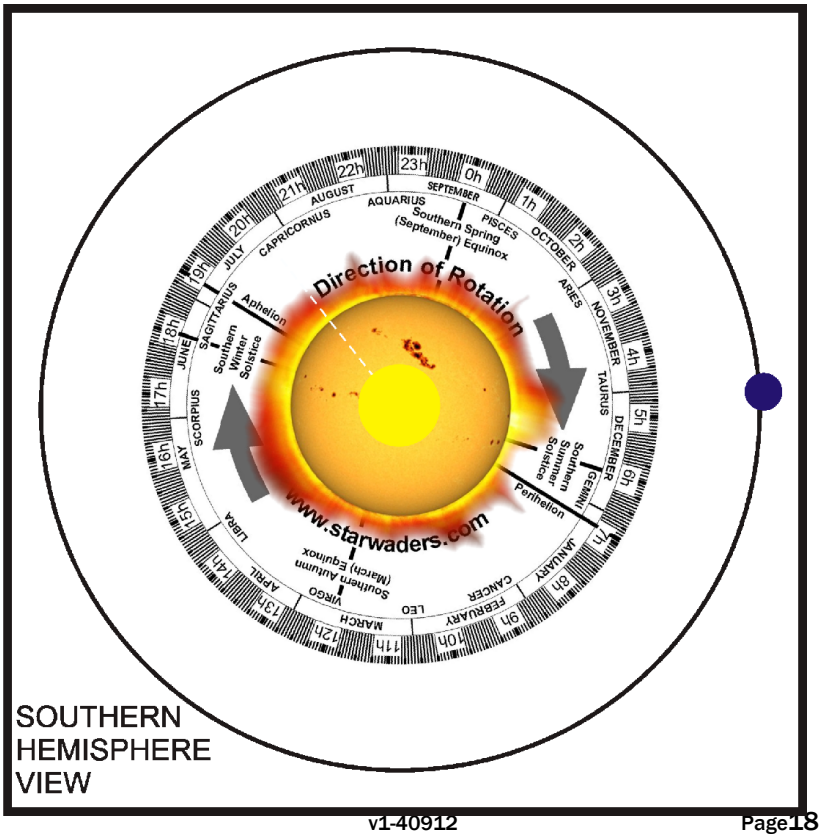


Heliocentric Longitudes of the Planets

The planets can also be positioned using their heliocentric coordinates, as opposed to positioning them according to the heavens-above.com website diagram as explained above. Heliocentric longitudes are the angular positions of the planets around the Sun and are usually given in degrees. These angles can be found for any time at http://www.planetary-aspects.com/curr_asp/curr_posns.php.

The RA values on the Sun disk can easily be calculated from the heliocentric degrees by remembering that every 1 hour of RA equals 15 degrees.

In this diagram Earth's heliocentric position is about 70 degrees, that is, 4h30*15min = 67.5 degrees. All the planets can be placed on the model with reference to the RA ring on the Sun disk.



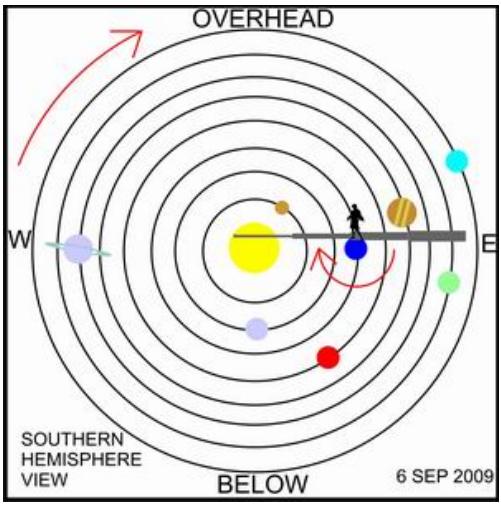
4.7 Early Evening Planet Positions

The planet positions used in these instructions are those of the 6th of September 2009.

With the model orientated so that it is parallel to the real Solar System, it now is roughly a miniature Solar System. In the diagram, when the Earth observer looks to the West along the horizon, the Sun has dipped below the horizon. Looking to the East, Jupiter has just risen. Uranus will rise soon and Neptune is about 20° above that horizon. As the horizon swivels clockwise, Mercury is heading to set in the West.

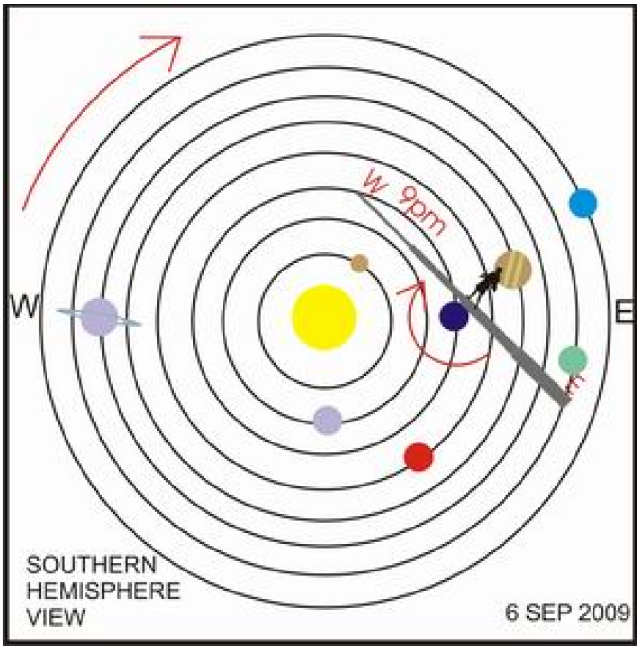
It is quite obvious that Mars, Saturn and Venus are on the far side of the Earth where they cannot be seen.

We can now swivel the horizon pointer clockwise – mimicking Earth's rotation - to see where the planets will be above the horizon as the night progresses.



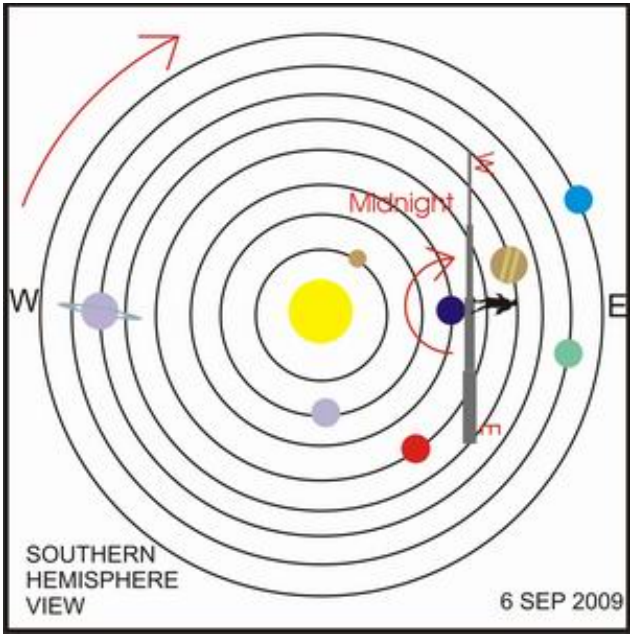
4.8 9pm Planet Positions

Three hours after sunset, the horizon shows that Jupiter and Neptune are nearly overhead. Uranus has just risen. Mercury has set.

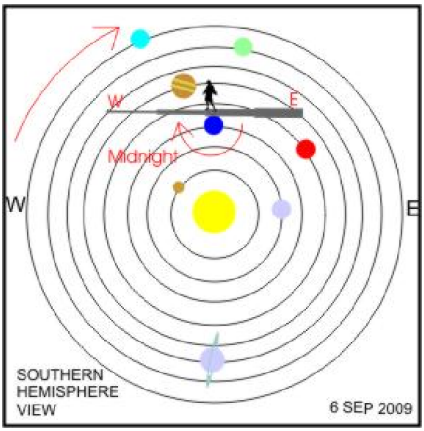


4.9 Midnight Planet Positions

At midnight the visible planets have moved a further 45° across the sky. No other planets have risen yet.



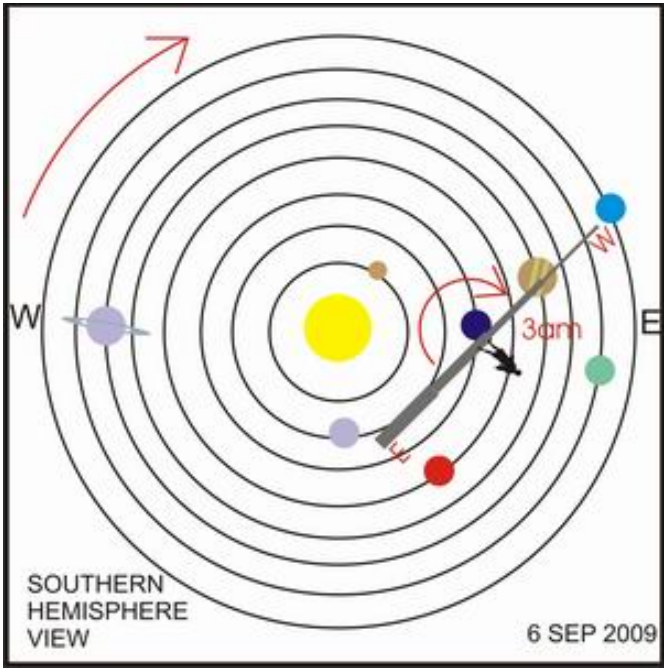
Note the special feature of the PSSM that to avoid the disconcerting effects of 'standing sideways', rotate the frame of the model anti-clockwise (in this case) until the model horizon is again level with the real horizon. Jupiter, Uranus and Neptune can clearly be seen to be overhead, as they are in the real overhead view.



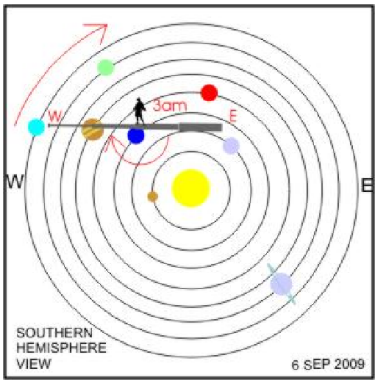
This feature applies to all the planet position images in this manual.

4.10 3am Planet Positions

At 3am, Jupiter and Neptune are about to set while Uranus is still high in the sky. Mars has now risen and Venus will rise shortly.



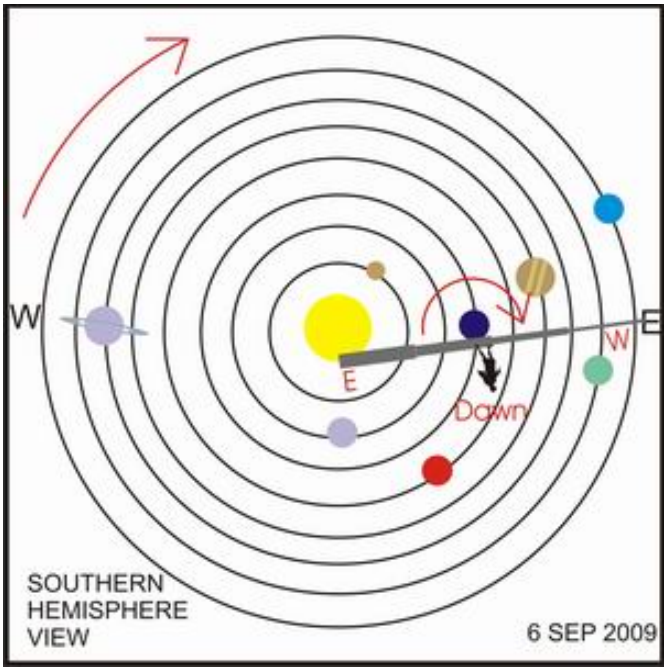
The PSSM rotated to the viewer upright position.



4.11 Dawn Planet Positions

Just before sunrise, Mars is high in the sky and Venus is well up.

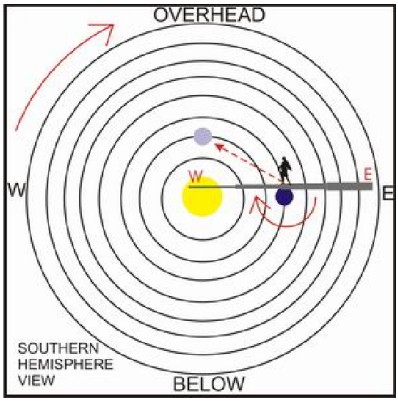
Note that Saturn has not been visible at any time during the night because it is so close to the Sun.

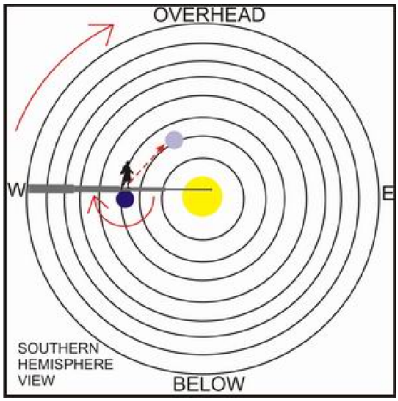


Remember that the PSSM to can be rotated to the viewer upright position.

4.12 The Morning and Evening Stars

Probably the most common question a layman asks is “Where is the evening star?” or “Oh, Venus is the evening star?” The Solar System model illustrates and explains how Venus is sometimes the evening star and at other times is the morning star. In fact, Jupiter can also be bright enough in the dawn or evening sky to deserve those titles.





In the first diagram, Venus is at a position where the viewer can see it 45° up in the evening sky and watch it set in the next few hours. It is thus the Evening Star. When it is the evening star, Venus trails the Earth in its orbit.

When Venus leads the Earth, as shown in the second diagram, it is seen the morning sky as shown in the second diagram. It is then called the Morning Star.

4.13 Earth’s Moon

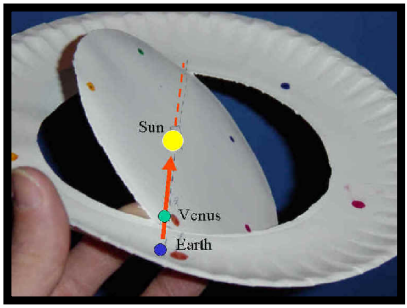
An idea presented here to show where the Earth’s Moon is is to use a tiny white polyball in the kit representing the Moon and sticking it in place using the short stick and a small blob of Prestik.

Note that at this scale, the Moon would be a little bigger and 1.2meters away from the Earth!!

(NOTE: In due course a better means of showing the Moon will be designed.)

4.14 Venus Transit

The Solar System model can be used in a special way to illustrate and explain how Venus moves across the face of the Sun and why it happens so seldom.

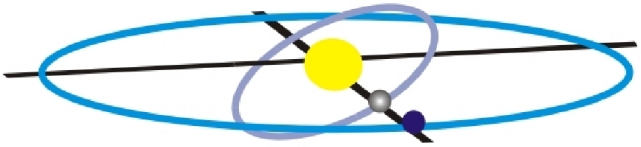


The planets do not all lie in the same orbital plane. The Earth's orbit is defined to be the standard plane of the solar system (called the ecliptic) and the orbital planes of all other planets are measured with respect to this ecliptic. At some point in their orbits, a planet will dip below the Earth's orbital plane and at other times will rise above it.

The only way Venus (or Mercury) will be seen from Earth to pass in front of the Sun is for it to be in exactly the same line from the Sun AND to be in the Earth's orbital plane. Every 588 days Venus does pass in between Earth and the Sun, but it is usually above or below the Sun when seen from Earth because Venus is either above or below the Earth's orbital plane. Only very seldom are they in line AND in the same orbital plane. For complex mathematical reasons it did so in 2004 and again in 2012 but will only do so again in 2117 and 2125.

How can the Solar System model demonstrate this?

Demonstrating the Venus transit only requires two hoops – one for Earth and one for Venus. Use the outer hoop (hoop 8) for Earth's orbit and hoop 6 Venus. Instead of fitting the hoop on top of the frame as usual, slide the Venus hoop over two opposite arms during assembly so that it dips below the frame on the one side and is tilted above the frame on the other side. The points where it mounts on the other two arms provides exactly the line-of-site orientation needed.



4.15 Solar Eclipse

Solar and Lunar eclipses can also be demonstrated by taking the Moon (the tiny polystyrene ball) and moving it around the Earth by hand.

4.16 Other Solar System Phenomena

The model can be used to demonstrate many configurations and movements of the solar system. Another example is the movement of Jupiter's moons. Ways to demonstrate further phenomena will be added to the www.starwaders.com.

5 Packing Away

If there are still young people around when it is time to go home, they can have some fun dismantling and packing the model away.

The plastic planets and Sun are packed into the bag first, (preferably a separate bag that itself is packed into the model's carry bag).

The hoops provide the fun. In order for all except the small orbits to fit into the carry bag, they need to be folded down to a smaller size.

The method is to twist one side while holding the other side still. The twist automatically makes the hoop contract into 3 smaller rings.

The outer orbits are too big to hold in two hands. Let the hoop dangle from one hand and place your foot on the end that is touching the ground. Twist the top end just more than half a turn while simultaneously lowering the hand to the ground – this allows the hoop to fold to the smaller size.

Once the hoops are packed away, disassemble the model.

6 A Short History of the PSSM

6.1 The Value of Understanding

I have always found more value in understanding the night sky as opposed to simply remembering star patterns. The movements of the planets between the stars confuses the general public while many an amateur astronomer has been known to find it difficult to interpret.

In my experience, people will remember something much better if they understand what and how it works. It does not help to tell the person that the Southern Cross will be on the other side of the sky in 6 months time – one has to explain how it moves and why it moves in that way.

6.2 Models

Being a practical guy, I needed a hands-on way to assist my explanations to others, let alone helping me to understand.

The first model I built was a simple one to demonstrate not only how the Southern Cross helps to find South, but also how it changes its orientation through the night and through the seasons.

The next model I built was to help explain retrograde movement of planets – that is, why they stop their usual movement among the stars going from west to east and for a short while move from east to west before resuming their usual movement.

When explaining the positions and movements of planets, it helps to be able to imagine yourself rising millions of kilometres towards the north or south celestial pole and looking down on the solar system. That mind experiment helps make sense of a planet's path across the sky – one can even imagine the planetary orbits being hoops straddling the night sky or, in the case of Venus and Mercury, slipping between Earth and the Sun.

Humans are Earth bound and 'down' is in the direction of the ground beneath one's feet. It takes very difficult mental gymnastics for many, especially the beginner, to imagine the actual orientation of the solar system where they are standing 'sideways' on the side of the Earth or 'upside-down' on the 'underside' of the Earth. This model helps to overcome this hurdle.

The closest I could get to this mind experiment was to build a model, which shows how the planets move and where their orbits are relative to Earth's orbit. This model easily explains why Venus is never seen overhead and why it alternates between being a morning star and at other times an evening star.

6.3 Traveling

I built my model in 1999. It is 2012 as I write. The model went with me to view a Total Solar Eclipse in Southern Africa on December 4, 2002. The picture shows me addressing a large crowd of 300 people the night before the eclipse, with the help of the model.

The local astronomy club goes to shopping centres to raise awareness of the club and astronomy. At one of these events, I noticed a mother helping her apparently blind daughter to feel the solar system. A special moment that was!

In June 2004 Venus passed across the surface of the Sun. Our astronomy club set up telescopes on the lawns of the local university. The model was there once again to help explain the phenomenon.

In November 2005 I travelled hundreds of kilometres to a mountain desert called the Richtersveld to show the stars to a select group of high school pupils.